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(54) HIGH STRENGTH STEEL SHEET HAVING EXCELLENT WELDABILITY AND HOLE EXPANSIBILITY AND PRODUCTION METHOD THEREFOR

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a high strength, high ductility steel sheet in which the weldablity and hole expansibility of a high strength steel sheet having a tensile strength of ≥800 MPa are simultaneously improved, and to provide a production method therefor.

SOLUTION: The high strength steel sheet having excellent weldability and hole expansibility has a composition containing, by mass, 0.01 to 0.20% C, 0.01 to 2.5% Si, 0.01 to 3% Mn, 0.0010 to 0.1% P, 0.0010 to 0.05% S,, and 0.005 to 2% Al, and further containing one or two kinds selected from 0.01 to 5.0% Mo and 0.001 to 1.0% Nb in the ranges so as to saatisfy the following inequality (A), and the balance Fe with inevitable impurities, and has a microstructure containing bainite or bainitic ferrite by ≥70% in an area ratio, and has a tensile strength of ≥800 MPa, and the production method uses the same high strength steel sheet: (3.0Nb+2.5Mo+1/10Si+Mn)-(2C0.5+2)>0 (A).

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Claim 1]At mass %, it is C. : 0.01 to 0.20%, Si : [0.01 to 2.5%,] Mn : 0.01 to 3%, P:0.0010 to 0.1%, S:0.0010 to 0.05%, aluminum : Contain 0.005 to 2% and further Mo:0.01-5.0%, Nb : 0.001 to 1.0% of one sort or two sorts are contained in the range with which the following (A) type is filled, A high intensity steel plate excellent in weldability and hole expansion property which the remainder is used as Fe and inevitable impurities, and a microstructure contains not less than 70% by an area rate as bainite or a BEINI tick ferrite, and are characterized by tensile strength being 800 or more MPa.

$3.0Nb+2.5Mo+1/(10\ Si+Mn)-(2C^{0.5}+2) > 0$ ... (A)

[Claim 2]They are Cr:0.01-5%, nickel:0.01-5%, Cu:0.01-5%, Co:0.01-5%, and W at mass %. : A high intensity steel plate excellent in weldability according to claim 1 and hole expansion property containing 0.01 to 5% of one sort, or two sorts or more.

[Claim 3]A high intensity steel plate excellent in weldability according to claim 1 or 2 and hole expansion property which are characterized by containing one sort of Zr, Hf, Ta, Ti, and V, or two sorts or more 0.001 to 1% in total by mass %.

[Claim 4]A high intensity steel plate excellent in weldability according to claim 1 to 3 and hole expansion property which are characterized by containing B:0.0001 to 0.1% by mass %.

[Claim 5]A high intensity steel plate excellent in weldability according to claim 1 to 4 and hole expansion property which are characterized by containing one sort of Ca, Y, and Rem, or two sorts or more 0.001 to 0.5% in total by mass %.

[Claim 6]Once cooling [directly or] casting slab which consists of the ingredient according to claim 1 to 5, it heats again, After it carries out after-pickling cold-rolling of the hot rolled sheet steel rolled round after hot-rolling and a maximum temperature at the time of afterbaking dull anneals below by more than $0.8x(Ac_3-Ac_1)+Ac_1$(**) Ac_3+30 (**), A manufacturing method of a high intensity steel plate excellent in weldability and hole expansion property cooling in a 200-500 ** temperature region with a cooling rate at 1-150 **/second, and holding for 1 second - 3000 seconds succeedingly in the temperature region.

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[Detailed Description of the Invention]
[0001]
[Field of the Invention]This invention relates to a high intensity steel plate excellent in weldability suitable for building materials, home electronics, a car, etc., and hole expansion property, and a manufacturing method for the same.
[0002]
[Description of the Prior Art]In recent years, especially in the car body, the demand of high intensity steel plates with the sufficient processability aiming at the viewpoint of fuel consumption improvement or durability enhancement is increasing. In addition, tensile strength is used from the needs of expansion of collision safety or a cabin space, and some steel plates more than 800 MPa class classes are being used for components, such as a lane force. Since ductility, bendability, hole expansion property, weldability, etc. pose a bigger problem than the high intensity steel plate up to about 590 MPa with tensile strength when finishing setting up a component using such a high strength material, the measure to these is needed. The following measures are respectively taken

against each characteristic.
[0003]For example, about hole expansion property, as it is in CAMP-ISIJ vol.13 (2000) p.395, a main phase -- bainite -- it is indicated that the punch stretchability of the present remains austenitic steel average is shown according to carrying out, raising hole expansion property and making the 2nd phase generate retained austenite also about a punch stretchability plasticity further. If the retained austenite of 2 to 3% of a volume rate is made to generate by carrying out austempering processing below at Ms temperature, it is also shown that tensile-strength x ****** serves as the maximum. However, it is not taken into consideration about the softening action in the weldability and the heat affected zone which are actualized exceeding 800MPa. About weldability, the softening action (HAZ softening action) in a heat affected zone is regarded as questionable in many cases. On the other hand, controlling a HAZ softening action by deposit of the carbide (Nb, Mo) C of Nb and Mo, as it is in JP,2000-87175,A, for example is shown. However, there is no consideration with this technology sufficient about processability, such as the hole expansion property etc. of what is taken into consideration about fatigue strength. An intensity level cannot say that it is low and the effect of control of a HAZ softening action is also enough about the weldability and the processability in a very high intensity material of 800 or more MPa. If tensile strength is especially set to 800 or more MPa, the welding itself will become difficult and it will become still more remarkable by 980 or more MPa. For this reason, there is also an example to which a part of laser welding etc. are applied in addition to the conventional welding processes, such as spot welding. However, as for high intensity reason base metal, the construction material change by the weld zone and a heat affected zone becomes very remarkable compared with the high strength material more than a 590MPa class especially.
[0004]In order to attain high ductility-ization of a high strength material, it is common to utilize complex tissue-ization positively. However, when martensite and retained austenite are utilized for the 2nd phase, there is a problem that hole expansion property will fall remarkably (for example, CAMP-ISIJ, vol.13 (2000), p.391). moreover -- the inside of this document -- a main phase -- a ferrite and the 2nd phase -- martensite -- although it carries out and it is indicated that the rate of hole expanding improves by decreasing both hardness difference, it is not remarkably improved with less than 70% at the rate of hole expanding.
[0005]
[Problem to be solved by the invention]This invention solves the problem of the above conventional technologies, and aims to let tensile strength provide a high intensity steel plate which has improved simultaneously the weldability of the high intensity steel plate of 800 or more MPa, and hole expansion property, and a manufacturing method for the same.
[0006]
[Means for solving problem]This invention persons are the fields of 800 or more MPa about tensile strength, as a result of examining many things, By performing limitation according microstructure **** to a component range or the (A) type as the technique of improving weldability and hole expansion property simultaneously. The softening action of the heat affected zone was controlled maintaining the high intensity of 800 or more MPa, and it found out further that rate of hole expanding:(bore-diameter-1 before inside diameter/hole expanding test of hole before hole expanding test) x100 could secure not

less than 70% of hole expansion property. This invention is as follows the place which was completed based on the above-mentioned knowledge and made into the summary.
[0007](1) At mass %, it is C. : 0.01 to 0.20%, Si : [0.01 to 2.5%,] Mn : 0.01 to 3%, P:0.0010 to 0.1%, S:0.0010 to 0.05%, aluminum : Contain 0.005 to 2% and further Mo:0.01-5.0%, Nb : 0.01 to 1.0% of one sort or two sorts are contained in the range with which the following (A) type is filled, The high intensity steel plate excellent in the weldability and hole expansion property which the remainder is used as Fe and inevitable impurities, and a microstructure contains not less than 70% by an area rate as bainite or a BEINI tick ferrite, and are characterized by tensile strength being 800 or more MPa.
$3.0Nb+2.5Mo+1/(10\ Si+Mn)-(2C^{0.5}+2) > 0$ ... (A)
(2) They are Cr:0.01-5%, nickel:0.01-5%, Cu:0.01-5%, Co:0.01-5%, and W at mass % further. : High intensity steel plate excellent in weldability and hole expansion property given in (1) containing 0.01 to 5% of one sort, or two sorts or more.
[0008](3) High intensity steel plate excellent in weldability and hole expansion property given in (1) further characterized by containing one sort of Zr, Hf, Ta, Ti, and V, or two sorts or more 0.001 to 1% in total by mass %, or (2).
(4) High intensity steel plate excellent in weldability and hole expansion property given in (1) further characterized by containing B:0.0001 to 0.1% by mass % thru/or (3).
[0009](5) High intensity steel plate excellent in weldability and hole expansion property given in (1) further characterized by containing one sort of Ca, Y, and Rem, or two sorts or more 0.001 to 0.5% in total by mass % thru/or (4).
Once cooling [directly or] the casting slab set to (6), (1) to (5) from the ingredient of a description, it heats again, After it carries out after-pickling cold-rolling of the hot rolled sheet steel rolled round after hot-rolling and the maximum temperature at the time of afterbaking dull anneals below by more than $0.8x(Ac_3-Ac_1)+Ac_1$(**) Ac_3+30 (**), A manufacturing method of the high intensity steel plate excellent in the weldability and hole expansion property cooling in a 200-500 ** temperature region with the cooling rate at 1-150 **/second, and holding for 1 second - 3000 seconds succeedingly in the temperature region.
[0010]
[Mode for carrying out the invention]Hereafter, this invention is explained in detail. Inventors are mass % and are C. : 0.01 to 0.2%, Si : [0.01 to 2.5%,] Mn : 0.01 to 3%, P:0.0010 to 0.1%, S:0.0010 to 0.05%, aluminum: 0.005 to 2% was contained, after-pickling cold-rolling of the hot rolled sheet steel for which each alloy was added and which was ingoted, was again heated as [casting] or once cooling, and was rolled round after hot-rolling was carried out based on the steel plate which consists of the remainder Fe and an inevitable impurity, it annealed after that, and the cold-rolled annealing board was created. About the steel plate, the hole expanding test of microstructure observation and steel league regulation, the tensile test based on JIS, and the steel plate were made to associate, laser welding was performed, the ballhead overhang examination was done after that, and comparative evaluation of each characteristic was carried out.
[0011]As a result, it found out that the high intensity steel plate which obtained the tensile strength of 800 or more MPa, and was excellent in weldability and hole expansion property by microstructure control obtained eventually could be manufactured. Next, the desirable microstructure of a base material steel plate is described. In order to fully secure hole expansion property, it was effective to have considered it as bainite or a BEINI tick

ferrite, and it decided to contain not less than 70% by an area rate. The bainite said here includes the both sides of the lower bainite which detailed carbide is generating in the upper bainite which carbide is generating on the Russ boundary, and Russ. A BEINI tick ferrite means bainite without carbide, for example, the Aqura ferrite is one of them. It is desirable for an area rate to exceed 97% by a main phase in the BEINI tick ferrite which does not have the lower bainite or carbide in which carbide is carrying out fine dispersion in improvement in hole expansion property.
[0012]On the other hand, the prevention from softening by a heat affected zone poses a problem. It shall be filling the (A) type which prescribed that an ingredient mentioned later to this, and tensile strength shall secure the weldability of the high strength material of 800 or more MPa. Considering the viewpoint of ductility reservation or high-intensity-izing, less than 30% of ferrite may also be included by an area rate. On the other hand, although it is not desirable from a point of the softening action of hole expanding processability or a heat affected zone to include austenite and/or martensite, as long as it is about less than 3% of an area rate, since remarkable characteristic degradation is not accepted, you may also contain less than 3% by an area rate. Inclusion, such as an oxide and a sulfide, may also be included unescapable.
[0013]In not satisfying a formula (A), in addition to the ability not to secure 800 or more MPa with tensile strength, or not control softening of a welding heat influence portion, it becomes difficult [reservation of hole expansion property].
$3.0Nb+2.5Mo+1/(10\ Si+Mn)-(2C^{0.5}+2) > 0$ ... (A)
As a remainder organization of a microstructure, also when 1 of carbide, a nitride, a sulfide, and an oxide or 2 or more [other than the above] were contained by 1% or less of an area rate, it could use by this invention, and these were included in the area rate of the main phase. Each phase of the above-mentioned microstructure, a ferrite (BEINI tick ferrite), Identification of bainite, austenite, martensite, an interfacial oxide phase, and a remainder organization, observation of an existence position, and measurement of an area rate, The reagent indicated by the Nay Taal reagent and JP,S59-219473,A corrodes a steel plate rolling direction section or a rolling rectangular-directions section, and it can quantify with 500 times - 1000 times as many observation by optical microscope and 1000 to 100000 times as many electron microscopes (a scanning-type and a transmission type). Observation of 20 or more views each can be performed, and the area rate of each organization can be searched for by the point counting method or image analysis.
[0014]Next, the Reason for limitation of the range with a preferred steel plate ingredient in this invention is explained. C is an element added in order to control the rate of the main phase for securing good intensity-hole-expansion-property balance, and the 2nd phase. It is affected also about detailed equalization of a base. In order to secure intensity and the area rate of each 2nd phase, the minimum was made into 0.001 mass % (it is the same hereafter), and it was considered as the maximum which can hold weldability and hole expansion property, and could be 0.20%. Preferably, good intensity-hole-expansion-property balance is obtained by considering it as C:0.03 to 0.10%. Si is an element added in order to control generation of the comparatively big and rough carbide which degrades intensity ductility balance, and made the minimum 0.01 mass %. superfluous addition made the maximum 2.5 mass %, weldability and in order are alike and to have an adverse effect. Preferably, a still more remarkable effect is acquired by considering it as Si:0.05-0.2%.

[0015]Mn is added for the purpose of high-intensity-izing. It is effective in controlling a ferrite transformation and making a main phase into bainite or a BEINI tick ferrite. It adds in order to control the carbide deposit which is one cause of strength reduction and hole-expansion-property degradation, and perlite generation. More than 0.01 mass % was used from these things. On the other hand, superfluous addition made 3 mass % the maximum, in order to promote martensite generation or to cause a ductile remarkable fall. Preferably, good intensity-hole-expansion-property balance is obtained by considering it as Mn:0.5-3.0%. P is a reinforcing element. Although low P-ization raised hole expansion property, since super-low-izing was economically disadvantageous, it made 0.0010 mass % the minimum. In abundant addition, in order to have an adverse effect on the manufacturability at weldability or the time of casting and hot-rolling, 0.1% was made into the maximum.
[0016]The reduction of S in S is effective in the improvement in hole expansion property. On the other hand, since super-low-izing was economically disadvantageous, it made 0.0010 mass % the minimum, and 0.05 mass % was made into the maximum at addition of the quantity exceeding this in order to have an adverse effect on the manufacturability at weldability or the time of casting and hot-rolling. aluminum is added as a deoxidizing element. For this reason, it was considered as the addition more than 0.005 mass %. On the other hand, superfluous addition made 2% the maximum in order to spoil weldability and a plating wettability.
[0017]Mo controls generation of carbide and perlite which degrade intensity-hole-expansion-property balance. The ferrite transformation was controlled, and since it was an important alloying element in order to obtain the very good balance of intensity-hole-expansion-property-weldability effective in making a main phase into bainite or a BEINI tick ferrite, and good, the minimum was made into 0.01 mass %. Since superfluous addition caused ductility degradation, it made the maximum 5.0%. Nb forms detailed carbide, a nitride, or carbon nitride, and is very effective in strengthening of a steel plate. A ferrite transformation is made delayed and generation of bainite and a BEINI tick ferrite is promoted. Since it was effective also for softening control of a heat affected zone, it was considered as the addition more than 0.01 mass %. On the other hand, since superfluous addition degraded ductility and hot-working nature, it was taken as 1.0 mass % as a maximum.
[0018]In order balance is good and to control weldability and hole expansion property by the intensity level of 800 or more MPa, we decided to satisfy a formula (A).
$3.0Nb+2.5Mo+1/(10\,Si+Mn)-(2C^{0.5}+2) > 0$ ... (A)
Target steel [this invention] can contain one sort of Cr, nickel, Cu, Co, and W, or two sorts or more for the purpose of the further improvement in intensity. It was an element added from the purpose of the strengthening purpose, control and bainite of carbide generation, and BEINI tick ferrite generation, Cr considered it as 0.01% or more, and in addition of the quantity exceeding 5%, it made this the maximum in order to have an adverse effect on processability. nickel was made more than 0.01 mass % for the purpose of [by improvement in hardenability] strengthening, and in addition of the quantity exceeding 5 mass %, it made this the maximum in order for processability, especially martensite to carry out hardness rise contribution and to have an adverse effect.
[0019]Cu considers it as the addition more than 0.01 mass % for the purpose of strengthening, and has an adverse effect on processability and manufacturability in

addition of the quantity exceeding 5 mass %. Co was taken as the addition more than 0.01 mass % for the good balance of the intensity-hole expansion property by transformation-to-bainite control. Although the maximum in particular of addition is not established, since it is an expensive element, it is on the other hand, desirable [abundant addition] to use below 5 mass % in order to spoil economical efficiency. W made the maximum that the strengthening effect shows up above 0.01 mass %, and 5 mass % at addition of the quantity exceeding this in order to have an adverse effect on processability.

[0020]Target steel [this invention] can contain one sort of Zr, Hf, Ta, Ti, and V which are strong carbide formation elements, or two sorts or more for the purpose of the further improvement in intensity. These elements formed detailed carbide, a nitride, or carbon nitride, and since it was very effective in strengthening of a steel plate, they considered one sort or two sorts or more as the addition more than 0.001 mass % in total if needed. On the other hand, since degradation of ductility or hot-working nature was caused, it was considered as 1 mass % as a maximum of one sort or two sorts or more of sum total additions. B can also be added if needed. By the addition more than 0.0001 mass %, although B was effective in strengthening of a grain boundary, or high-intensity-izing of steel materials, since the effect is not only saturated, but processability would fall if the addition exceeds 0.1 mass %, it made the maximum 0.1 mass %.

[0021]Since a proper quantity of Ca, Y, and Rem(s) contributed to inclusion control, especially fine dispersion-ization by addition, they considered it as 0.001% or more, and in order that superfluous addition might reduce manufacturability, such as fluidity and hot-working nature, and the ductility of steel sheet products by one side, 0.5 mass % was made into the maximum. Although there are N, Sn, etc. as inevitable impurities, for example, even if it contains these elements in the range below 0.02 mass %, the effect of this invention is not spoiled. the high intensity steel plate excellent in the weldability which has such an organization, and hole expansion property -- the manufacturing method to call is explained below.

[0022]After-hot-rolling cold-rolling and in annealing and manufacturing the steel plate of this invention, it reheats, once cooling [directly or] the slab adjusted to the predetermined ingredient, and performs hot-rolling. The reheating temperature at this time has desirable not less than 1100 ** thing to consider as 1300 ** or less. If reheating temperature becomes an elevated temperature, coarse-grain-izing and the thick scale will be formed, and on the other hand by low-temperature heating, rolling resistance will become high. After hot-rolling is advantageous when the surface cleaning in a product will plate by becoming good, if surface scale deletion is performed by a high voltage descaling unit, carrying out pickling, etc. Then, it is considered as a final product by carrying out cold-rolled afterbaking dull. Even if it performs electroplating, hot dip zincing, and melting alloy galvanization, the invention in this application is not checked. Although it is common to carry out above the Ar_3 temperature of transformation decided by the chemical entity of steel as for hot-rolled completion temperature, if about 10 ** is to low temperature, the characteristic of a final steel plate will not be degraded from Ar_3. Although the coiling temperature after cooling is making it more than the transformation-to-bainite starting temperature decided by the chemical entity of steel and raising the load at the time of cold-rolling more than needed is avoided, When the bottom rate of total pressure of cold-rolling is small, it is not this limitation, and even if rolled round below at the transformation-to-bainite temperature of steel, the characteristic of a final steel plate

is not degraded. Although set to the last board thickness from the relation of cold-rolled load, if the bottom rate of total pressure of cold-rolling is not less than 40%, it will be enough for making it recrystallize, and will not degrade the characteristic of a final steel plate.
[0023]Temperature Ac1 and Ac3 as which annealing temperature is decided by the chemical entity of steel when carrying out cold-rolled afterbaking dull at temperature (for example, "ferrous material study":wcLeslie work, Nariyasu Koda supervision of translation, Maruzen P273). Since the case of less than $0.8x(Ac_3-Ac_1)+Ac_1$ (**) expressed has few amounts of austenites obtained with annealing temperature, bainite or a BEINI tick ferrite cannot be made to mainly generate in a final steel plate. Big-and-rough-izing and scaling of a crystal grain are promoted so that annealing temperature serves as an elevated temperature, and also the rise of the manufacturing cost was imitated and the maximum of annealing temperature was set to Ac_3+30 (**) at the ** sake. 10 seconds or more are required for the annealing time in this temperature region because of reservation of temperature equalization of a steel plate, and austenite. However, in more than 30 minutes, internal oxidation phase formation is promoted, and also the rise of cost is caused. The subsequent primary cooling of concrete is important for bainite or carrying out BEINI tick ferrite generation, **(ing) the transformation to a ferrite phase from an austenite phase to some extent. Since there was concern which promotes generation of a ferrite or perlite and causes strength reduction, carrying out [second] this cooling rate in less than 1 ** /made the minimum of the cooling rate a second in 1 ** /. On the other hand, since a becoming [hard phases, such as a martensitic phase in a final steel plate, / abundant] and operation top was difficult when a cooling rate is more than 150 **/second, this was made into the maximum.
[0024]If this primary cooling of concrete was performed to less than 200 **, in order that martensite might generate so much and might promote hole expansion property and delayed fracture during cooling, cooling-shut-down temperature was 200-500 **. This was made into a maximum, in order that carbide might generate for a short time and might cause strength reduction at the time of subsequent maintenance, if cooling-shut-down temperature exceeded 500 **. In order to urge advance of a transformation to bainite next, maintenance in this temperature region is performed. When this retention time turns into a long time, on productivity, it is not desirable, and also since carbide generates, it is desirable to consider it as less than 3000 seconds. In order to carry out transformation-to-bainite advance, it is desirable to hold 1 second or more and to hold from 15 seconds preferably for 20 minutes. At less than 200 **, a transformation to bainite does not happen easily, and if it exceeds 500 **, it will become difficult for carbide to arise and to leave sufficient retained austenite phase. About a welding process, even if it welds a welding process usually performed, for example, an arc, TIG, MIG, mash, laser, etc., it is considered as the range of an application concerned.
[0025]
[Working example]Hereafter, an embodiment explains this invention still in detail. After pickling, cold-rolling of the steel strip in coil rolled round above transformation-to-bainite starting temperature which heats a steel plate of a presentation as shown in Table 1 at 1200 **, completes hot-rolling above the Ar_3 temperature of transformation, and is decided by a chemical entity of after-cooling each steel was carried out, and it was made into 1.2-mm thickness. Then, according to a following formula, it asked for Ac_1 and the

Ac_3 temperature of transformation by calculation from an ingredient (mass %) of each steel.
Ac_1=723-10.7xMn%+29.1xSi%, Ac_3=910-203x(C %) $^{1/2}$-15.2xnickel%+44.7xSi%+104xV%+31.5xMo%-30xMn%-11xCr%+400xaluminum%, It cooled, after carrying out the retention, cooling to 200-450 ** to annealing temperature calculated from these Ac_1 and the Ac_3 temperature of transformation and holding [temperature up and] for 1 to 3000 seconds succeedingly with a cooling rate at 3-150 **/second in 10%H_2-N_2 atmosphere to it.
[0026]A piece of a JIS No. 5 tensile test was extracted from these steel plates, and mechanical properties were measured. A hole expanding test was done based on a steel league standard, and it asked for a rate of hole expanding. Laser welding which made a steel plate associate about weldability was performed, a ballhead overhang examination was done in resin sheet lubrication, and overhang height and a fracture position over base metal were measured. A microstructure and each construction material are shown in Table 2, and each manufacturing conditions and construction material are shown in Table 3. It turns out that invention steel which fills an outline of the invention in this application is excellent in weldability, ductility, intensity (they are 800 or more MPa at tensile strength), and hole expansion property. As for a comparative example from which it separates from conditions of this invention on the other hand, it is inferior in strength any of ballhead overhang height of a weld zone, tensile strength, and hole expansion property they are. Relation between a value which squared ballhead overhang height ratio:R [of a weld zone], tensile strength:TS/MPa, and rate of hole expanding:lambda=1-d/d_0 (a bore diameter/mm after d:hole expanding test, d_0: a basis bore diameter / mm), and a value of a formula (A) is shown in drawing 1. It turns out that all of the 3 characteristics of the processability of a good weld zone, tensile strength, and hole expansion property are good with invention steel which fills both an organization a process and a formula (A).
[0027]
[Effect of the Invention]By this invention, tensile strength can obtain a high intensity high ductility steel plate which has improved simultaneously the weldability of the high intensity steel plate of 800 or more MPa, and hole expansion property, and a manufacturing method for the same.
[Table 1]

表1　化学成分

鋼種番号	C	Si	Mn	AL	P	S	Mo	Nb	Cr	Ni	Cu	Co	W	Ti	V	Zr	Hf	Ta	B	Ca	Y	Rem	式(A)の値	備考
A	0.12	0.74	1.92	0.03	0.022	0.005	0.13	0.015															0.18659	発明鋼
B	0.19	1.21	1.84	0.04	0.013	0.004	0.08	0.028															0.12812	発明鋼
C	0.18	1.12	1.81	0.02	0.013	0.006	0.21	0.011															0.338858	発明鋼
D	0.11	0.68	1.65	0.05	0.008	0.006	0.22	0.015	0.11			0.02	0.11										0.13551	発明鋼
E	0.18	0.98	1.96	0.03	0.015	0.002	0.11	0.022		0.12	0.15	0.01								0.0009			0.178526	発明鋼
F	0.13	0.62	2.05	0.02	0.025	0.003	0.09	0.013								0.01						0.001	0.098057	発明鋼
G	0.09	0.45	1.69	0.02	0.01	0.005	0.18	0.023									0.005	0.01			0.0005		0.019	発明鋼
H	0.11	0.98	2.2	0.03	0.02	0.004	0.14	0.008							0.24								0.66451	発明鋼
I	0.21	1.3	2.25	0.01	0.02	0.003	0.01	0.033						0.02									0.386674	発明鋼
J	0.14	1.05	1.56	0.02	0.01	0.002	0.16	0.009											0.0025				0.026418	発明鋼
K	0.15	1.2	1.95	0.04	0.005	0.003	0.14	0.026															0.487214	発明鋼
L	0.21	0.5	2.45	0.15	0.012	0.005	0.05	0.042															0.180341	発明鋼
M	0.12	1.1	2.23	0.03	0.008	0.007	0.02	0.056															0.58459	発明鋼
N	0.17	0.8	2.12	0.04	0.009	0.008	0.2	0.021															0.468019	発明鋼
O	0.09	1.3	1.95	0.05	0.013	0.009	0.16	0.032															0.822667	発明鋼
P	0.15	0.6	1.78	0.51	0.025	0.007	0.31	0.015															0.309214	発明鋼
Q	0.14	1.2	1.89	0.03	0.007	0.008	0.26	0.032															0.575419	発明鋼
R	0.09	0.9	2.05	0.04	0.005	0.004	0.19	0.011											0.0012				0.668	発明鋼
S	0.16	0.85	1.87	0.05	0.007	0.006	0.17	0.033															0.307333	発明鋼
CA	0.18	1.5	1.4	0.03	0.01	0.003																	-0.3758	比較鋼
CB	0.07	0.3	2.3	0.03	0.02	0.004	1.5	0.5															5.341477	比較鋼
CC	0.13	1.5	1.68	0.03	0.01	0.004								0.81	0.75				0.25				0.050723	比較鋼
CD	0.06	0.52	2.98	0.05	0.02	0.005			7.5	4.5												0.75	0.963284	比較鋼
CE	0.22	2.65	2.2	0.04	0.02	0.002																	1.087871	比較鋼

[Table 2]

表2 各鋼のミクロ組織、機械的特性と溶接性

鋼種番号	処理番号	主相の種類＊	ベイナイト＋ベイニティックフェライトの面積率(%)	フェライトの面積率(%)	マルテンサイトの面積率(%)	オーステナイトの面積率(%)	パーライトの面積率(%)	(B)式の値	主相と第2相の硬度比:第2相硬度／主相硬度	溶接方法	球頭張り出し試験の破断位置	球頭張出し試験の張り出した高さ比:継ぎ手／母材	引張り強度(Mpa)	伸び(%)	穴拡げ率(%)	鋼種番号	備考
A	1	ベイナイト＋ベイニティックフェライト	84	5	2	9	0	4.5	1.3	レーザー	母材	0.85	1160	17	85	A	発明鋼
A	2	ベイナイト＋ベイニティックフェライト	81	9	0	10	0	∞	1.2	レーザー	母材	0.92	1010	18	80	A	発明鋼
A	2	ベイナイト＋ベイニティックフェライト	81	9	0	10	0	∞	1.2	TIG	母材	0.82	1010	18	80	A	発明鋼
A	2	ベイナイト＋ベイニティックフェライト	81	9	0	10	0	∞	1.2	アーク	母材	0.75	1010	18	80	A	発明鋼
A	3	フェライト	25	52	0	0	23	∞	1.2	レーザー	母材	0.9	850	22	45	A	比較鋼
B	1	ベイナイト＋ベイニティックフェライト	72	12	4	12	0	3	1.3	レーザー	母材	0.84	1190	14	80	B	発明鋼
B	2	ベイナイト＋ベイニティックフェライト	68	15	0	17	0	∞	1.2	レーザー	母材	0.91	1180	15	80	B	発明鋼
C	1	ベイナイト＋ベイニティックフェライト	74	11	0	15	0	∞	1.2	レーザー	母材	0.92	1220	13	90	C	発明鋼
C	2	ベイナイト＋ベイニティックフェライト	72	12	3	13	0	4.3	1.3	レーザー	母材	0.92	1230	12	85	C	発明鋼
C	2	ベイナイト＋ベイニティックフェライト	72	12	3	13	0	4.3	1.3	アーク	母材	0.79	1230	12	85	C	発明鋼
C	3	ベイナイト＋ベイニティックフェライト	46	13	34	7	0	0.2	1.8	レーザー	溶接熱影響部	0.61	1410	5	40	C	比較鋼
D	1	ベイナイト＋ベイニティックフェライト	74	4	7	15	0	2.1	1.2	レーザー	母材	0.85	1380	10	70	D	発明鋼
E	1	ベイナイト＋ベイニティックフェライト	66	18	4	12	0	3	1.2	レーザー	母材	0.85	1280	10	70	E	発明鋼
F	1	ベイナイト＋ベイニティックフェライト	74	7	6	13	0	2.2	1.2	レーザー	母材	0.84	1380	10	70	F	発明鋼
F	2	ベイナイト＋ベイニティックフェライト	81	4	0	15	0	∞	1.2	レーザー	母材	0.83	1350	11	75	F	発明鋼
G	1	ベイナイト＋ベイニティックフェライト	81	2	5	12	0	2.4	1.2	レーザー	母材	0.75	1300	11	80	G	発明鋼
H	1	ベイナイト＋ベイニティックフェライト	77	10	4	9	0	2.3	1.3	レーザー	母材	0.81	1190	12	75	H	発明鋼
H	2	ベイナイト＋ベイニティックフェライト	73	12	0	15	0	∞	1.2	レーザー	母材	0.85	1200	12	75	H	発明鋼
I	1	ベイナイト＋ベイニティックフェライト	73	10	4	13	0	3.3	1.3	レーザー	母材	0.89	1450	8	75	I	発明鋼
I	2	ベイナイト＋ベイニティックフェライト	77	7	0	16	0	∞	1.2	レーザー	母材	0.85	1390	9	80	I	発明鋼
I	3	フェライト	30	45	25	0	0	0	1.9	レーザー	溶接熱影響部	0.56	1350	5	35	I	比較鋼
J	1	ベイナイト＋ベイニティックフェライト	75	10	3	12	0	4	1.3	レーザー	母材	0.81	1210	11	75	J	発明鋼
J	1	ベイナイト＋ベイニティックフェライト	75	10	3	12	0	4	1.3	アーク	母材	0.71	1210	11	75	J	発明鋼
J	2	ベイナイト＋ベイニティックフェライト	74	9	0	17	0	∞	1.2	レーザー	母材	0.82	1190	12	70	J	発明鋼
J	2	ベイナイト＋ベイニティックフェライト	74	9	0	17	0	∞	1.2	アーク	母材	0.7	1190	12	70	J	発明鋼
K	1	ベイナイト＋ベイニティックフェライト	79	6	0	15	0	∞	1.3	レーザー	母材	0.96	1250	10	80	K	発明鋼
L	1	ベイナイト＋ベイニティックフェライト	78	3	5	14	0	2.8	1.2	レーザー	母材	0.95	1490	8	80	L	発明鋼
M	1	ベイナイト＋ベイニティックフェライト	79	9	0	12	0	∞	1.3	レーザー	母材	0.93	1290	10	75	M	発明鋼
N	1	ベイナイト＋ベイニティックフェライト	82	5	3	10	0	3.3	1.3	レーザー	母材	0.94	1180	12	80	N	発明鋼
O	1	ベイナイト＋ベイニティックフェライト	80	8	0	12	0	∞	1.2	レーザー	母材	0.93	1250	11	75	O	発明鋼
P	1	ベイナイト＋ベイニティックフェライト	82	2	5	11	0	2.2	1.3	レーザー	母材	0.96	1220	10	80	P	発明鋼
Q	1	ベイナイト＋ベイニティックフェライト	81	6	0	13	0	∞	1.3	レーザー	母材	0.91	1200	11	80	Q	発明鋼
R	1	ベイナイト＋ベイニティックフェライト	81	3	4	12	0	3	1.4	レーザー	母材	0.89	1280	9	80	R	発明鋼
S	1	ベイナイト＋ベイニティックフェライト	82	4	3	11	0	3.7	1.3	レーザー	母材	0.9	1300	10	75	S	発明鋼
CA		ベイナイト＋ベイニティックフェライト	53	33	0	14	0	∞	1.3	レーザー	溶接熱影響部	0.56	785	26	45	CA	比較鋼
CB		ベイナイト	98	0	2	0	0	0	1.4	レーザー	溶接熱影響部	0.55	1240	5	75	CB	比較鋼
CC		熱延時に割れ	測定不可	測定不可	測定不可	測定不可	測定不可									CC	比較鋼
CD		熱延時に割れ	測定不可	測定不可	測定不可	測定不可	測定不可									CD	比較鋼
CE		フェライト	23	60	0	17	0	∞	1.7	レーザー	母材	0.85	1120	21	30	CE	比較鋼

＊各層の体積分率の合計100%となるが、炭化物、酸化物、硫化物および窒化物等の光学顕微鏡レベルでは観察同定困難な相については主相の体積率に加えた。

[Table 3]

表3 各鋼の製造方法と機械的特性および溶接性

鋼種番号	処理番号	主相の種類＊	AC1 (℃)	AC3 (℃)	0.8(AC3−AC1)+AC1 (℃)	AC3+30 (℃)	焼鈍温度 (℃)	冷却速度 (℃/s)	冷却停止温度 (℃)	保持温度(℃)×保持時間(s)	溶接方法	球頭張り出し試験の破断位置	球頭張出し試験の張り出した高さ比：継ぎ手／母材	引張り強度 (Mpa)	伸び (%)	穴拡げ率 (%)	鋼種番号	備考
A	1	ベイナイト＋ベイニティックフェライト	724	847	822	877	850	100	220	420℃×30S	レーザー	母材	0.85	1160	17	85	A	発明鋼
A	2	ベイナイト＋ベイニティックフェライト	724	847	822	877	850	100	350	350℃×300S	レーザー	母材	0.92	1010	18	80	A	発明鋼
A	2	ベイナイト＋ベイニティックフェライト	724	847	822	877	850	100	350	350℃×300S	TIG	母材	0.82	1010	18	80	A	発明鋼
A	2	ベイナイト＋ベイニティックフェライト	724	847	822	877	850	100	350	350℃×300S	アーク	母材	0.75	1010	18	80	A	発明鋼
A	3	フェライト	724	847	822	877	800	1	450	450℃×600S	レーザー	母材	0.9	850	22	45	A	比較鋼
B	1	ベイナイト＋ベイニティックフェライト	739	848	826	878	840	80	250	400℃×100S	レーザー	母材	0.84	1190	14	80	B	発明鋼
B	2	ベイナイト＋ベイニティックフェライト	739	848	826	878	840	80	350	350℃×180S	レーザー	母材	0.91	1180	15	80	B	発明鋼
C	1	ベイナイト＋ベイニティックフェライト	736	843	822	873	820	100	250	400℃×180S	レーザー	母材	0.92	1220	13	90	C	発明鋼
C	2	ベイナイト＋ベイニティックフェライト	736	843	822	873	820	100	350	350℃×400S	レーザー	母材	0.92	1230	12	85	C	発明鋼
C	2	ベイナイト＋ベイニティックフェライト	736	843	822	873	820	100	350	350℃×400S	アーク	母材	0.79	1230	12	85	C	発明鋼
C	3	ベイナイト＋ベイニティックフェライト	736	843	822	873	900	120	100	200℃×10S	レーザー	溶接熱影響部	0.61	1410	5	40	C	比較鋼
D	1	ベイナイト＋ベイニティックフェライト	727	855	829	885	850	80	350	420℃×180S	レーザー	母材	0.85	1390	10	70	D	発明鋼
E	1	ベイナイト＋ベイニティックフェライト	729	833	812	863	830	100	350	400℃×100S	レーザー	母材	0.85	1290	10	70	E	発明鋼
F	1	ベイナイト＋ベイニティックフェライト	719	831	809	861	830	100	350	400℃×180S	レーザー	母材	0.84	1380	10	70	F	発明鋼
F	2	ベイナイト＋ベイニティックフェライト	719	831	809	861	840	110	350	350℃×300S	レーザー	母材	0.83	1350	11	75	F	発明鋼
G	1	ベイナイト＋ベイニティックフェライト	718	839	815	869	840	100	350	390℃×180S	レーザー	母材	0.75	1300	11	80	G	発明鋼
H	1	ベイナイト＋ベイニティックフェライト	728	876	846	906	870	80	400	400℃×150S	レーザー	母材	0.81	1190	12	75	H	発明鋼
H	2	ベイナイト＋ベイニティックフェライト	728	876	846	906	870	80	350	370℃×600S	レーザー	母材	0.85	1200	12	75	H	発明鋼
I	1	ベイナイト＋ベイニティックフェライト	737	834	814	864	840	80	350	400℃×150S	レーザー	母材	0.89	1450	8	75	I	発明鋼
I	2	ベイナイト＋ベイニティックフェライト	737	834	814	864	840	80	350	350℃×300S	レーザー	母材	0.85	1390	9	80	I	発明鋼
I	3	フェライト	737	834	814	864	750	70	200	保持無	レーザー	溶接熱影響部	0.56	1350	5	35	I	比較鋼
J	1	ベイナイト＋ベイニティックフェライト	737	854	831	884	850	70	350	370℃×600S	レーザー	母材	0.81	1210	11	75	J	発明鋼
J	1	ベイナイト＋ベイニティックフェライト	737	854	831	884	850	70	350	370℃×600S	アーク	母材	0.71	1210	11	75	J	発明鋼
J	2	ベイナイト＋ベイニティックフェライト	737	854	831	884	850	70	400	400℃×300S	レーザー	母材	0.82	1190	12	70	J	発明鋼
J	2	ベイナイト＋ベイニティックフェライト	737	854	831	884	850	70	400	400℃×300S	アーク	母材	0.7	1190	12	70	J	発明鋼
K	1	ベイナイト＋ベイニティックフェライト	737	850	828	880	850	70	350	350℃×300S	レーザー	母材	0.96	1250	10	80	K	発明鋼
L	1	ベイナイト＋ベイニティックフェライト	711	836	811	866	850	70	350	400℃×300S	レーザー	母材	0.95	1490	8	80	L	発明鋼
M	1	ベイナイト＋ベイニティックフェライト	731	840	818	870	850	70	350	350℃×300S	レーザー	母材	0.93	1290	10	75	M	発明鋼
N	1	ベイナイト＋ベイニティックフェライト	724	827	806	857	850	70	350	400℃×300S	レーザー	母材	0.94	1180	12	80	N	発明鋼
O	1	ベイナイト＋ベイニティックフェライト	740	883	854	913	870	80	400	400℃×300S	レーザー	母材	0.93	1250	11	75	O	発明鋼
P	1	ベイナイト＋ベイニティックフェライト	721	###	973	1066	1000	120	350	400℃×300S	レーザー	母材	0.96	1220	10	80	P	発明鋼
Q	1	ベイナイト＋ベイニティックフェライト	740	862	838	892	850	70	350	350℃×300S	レーザー	母材	0.91	1200	11	80	Q	発明鋼
R	1	ベイナイト＋ベイニティックフェライト	727	853	828	883	850	70	400	400℃×300S	レーザー	母材	0.89	1280	9	80	R	発明鋼
S	1	ベイナイト＋ベイニティックフェライト	731	845	822	875	850	70	350	400℃×300S	レーザー	母材	0.9	1300	10	75	S	発明鋼
CA		ベイナイト＋ベイニティックフェライト	752	868	845	898	850	80	450	420℃×300S	レーザー	溶接熱影響部	0.56	785	26	45	CA	比較鋼
CB		ベイナイト	707	827	803	857	830	30	420	400℃×300S	レーザー	溶接熱影響部	0.55	1240	5	75	CB	比較鋼
CE		フェライト	778	897	873	927	880	25	400	400℃×360S	レーザー	母材	0.85	1120	21	30	CE	比較鋼